APPENDIX IE-2. Example of a conceptual model for use in understanding factors and activities that affect the Region's ability to achieve desired conditions.

Tahoe Monitoring & Evaluation Program

Title: Biological Integrity of Aquatic Ecosystems Desired Condition – Biological Integrity of Streams Objective

Conceptual Model & Indicator Framework Narrative Documentation

Version 0.65

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The conceptual models developed for the Tahoe Status and Trend Monitoring and Evaluation Program (M&E Program) provide clear representations of systems related to desired conditions that can be used by agency management. The Tahoe M&E Program conceptual models provide a framework to:

- Understand the most important drivers affecting the status of the systems related to desired conditions
- Assist in the selection and interpretation of meaningful indicators to track the status of the systems related to the desired conditions
- Identify the most influential actions for achieving desired conditions and appropriate *performance measures* to characterize how actions incrementally contribute to achieving desired conditions
- Identify key research priorities related to the M&E Program and resource management actions.

The conceptual model and related indicator framework are documented with narrative descriptions, diagrams, and tables. The elements of the conceptual model and indicator framework, their locations within the products, and the relationships between the elements are shown in Figure 1. If you are interested in gaining a brief overview of the conceptual model diagram, please skip to the Conceptual Model Diagram Overview section.

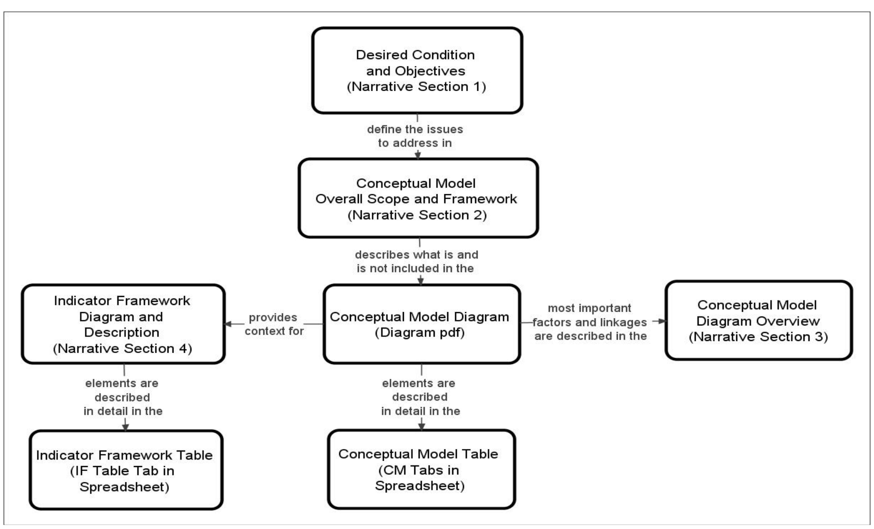

Figure 1: Relationship between CM & IF elements and where each element can be found.

Section 1 – Desired Condition & Objectives

This section presents the Biological Integrity of Aquatic Ecosystems desired condition (with a focus on the stream biological integrity component) that was developed by the Wildlife and Fisheries Technical Working Group (TWG) and vetted through the Pathway planning process. This section also highlights other desired conditions identified in the Pathway planning process that relate to stream system condition and defines an interim, time-specific, and measurable stream biological condition objective to clarify the intent of the Biological Integrity of Aquatic Ecosystems desired condition statement. Although this conceptual model and indicator framework is explicitly limited to consideration of streams within the Tahoe Basin, we expect it will serve as a model in future efforts to define conceptual models and indicator frameworks for wetlands, small lakes, and Lake Tahoe itself.

Biological Integrity of Aquatic Ecosystems Desired Condition

The functional, physical, chemical and biological integrity of the Basin's aquatic ecosystem are maintained at a sustainable level.

Streams and associated riparian environments encompass diverse natural resource values. According to Pathway documents, the Wildlife and Fisheries desired condition promotes the natural condition of aquatic ecosystems, including Lake Tahoe, wetlands, small lakes, and streams. Per Pathway documentation, the desired condition is based on Karr and Dudley's (1981) definition of biological integrity – "*the capability of supporting and maintaining a balanced, integrated, adaptive community of organisms having a species composition, diversity, and functional organization comparable to that of the natural habitat of the region.*" It guides managers to maintain and protect aquatic environments that are biologically, physically, and chemically intact and identifies areas for possible restoration that are outside a desired range of conditions.

The Pathway Wildlife and Fisheries TWG document also recognized that impacts from human development and alien or introduced species will persist due to on-the-ground realities, such as residential development in stream zones, and some Basin agencies' management goals that strive to perpetuate "desirable" non-native fish species.

Streams and their associated riparian habitats are key components of Lake Tahoe Basin's aquatic ecosystems and important to people as exemplified by the breadth of desired conditions expressed by different Pathway Technical Working Groups. Likewise, concern for stream water quality and biological condition is embodied in various federal, state, and regional water quality laws, regulations, and ordinances, including the Clean Water Act, 208 Water Quality Plan, TRPA Code of Ordinances, California and Nevada state water quality standards. Streams and associated environments significantly contribute to the Tahoe Basin's biological diversity provide people with a place for recreation and reflection. Consequently, people are interested in knowing the condition of streams and how stream condition is changing; they want to know whether a stream is healthy.

One objective for the biological integrity of streams has been identified for the Biological Integrity of Aquatic Ecosystems desired condition. Biological integrity objectives for other aquatic ecosystem components (Lake Tahoe, small lakes and wetlands) will be developed at a later date. Establishing an objective for biological integrity of streams reflects a broad scientific understanding that the resident biological community is a reliable indicator of the health of the stream, the adjacent riparian environment, and even the entire watershed (Roth et al. 1996, Karr and Chu 1999, Tom Suk, pers. comm., and others).

Streams collect water across landscapes, including areas affected by urban development and areas of varying intensities of human use; stream organisms manifest degradation of adjoining areas as well as effects on the stream itself. The biological integrity of streams objective recognizes that urban development and associated activities exist in the Basin and that in some cases, restoration of biological conditions to that which would be expected under natural condition will not be feasible. The importance of this issue is recognized in the designated use provision of the Clean Water Act and in the plan for development and use of indicators (e.g., urban vs. wildland specific thresholds and criteria) within the Tahoe Basin.

Biological Integrity of Streams Objective

Stream and riparian zones meet biological condition targets established for urban and wildland stream settings within each evaluation period. A diversity of native plants and animals adapted to an oligotrophic, cold-water Sierra Nevada stream ecosystem is present. For each region within the Tahoe Basin, the integrity objective implies that the fauna is dominated by native species and assemblages adapted to oligotrophic, cold-water systems, in contrast to the kinds of species and assemblages that might be found outside of the Tahoe Region, such as species assemblages typically observed in eutrophic or mesotrophic warm and cool water systems.

Milestones

- Implement a regional stream monitoring and evaluation plan in 2009.
- Use previous research and monitoring efforts and new monitoring data to provide scientific basis for biological conditions targets for urban and wildland settings within 3 years.
- Allow policy-makers and citizens an opportunity to evaluate and provide input on proposed biological condition targets and adjust as appropriate within 6 months of scientific recommendations.
- After targets have been established, implement monitoring and compare observed indicator values against target values on an annual basis.

Discussion

Although bioassessment has been widely used to assess stream condition nationally and internationally for almost three decades (see appendix in Karr 2006), its application in the Lake Tahoe Basin is relatively recent (e.g., Herbst et al. 2006, Fore 2007, Herbst and Sildorff 2009). These efforts produced two multimetric indexes that could be used in the Tahoe Basin. First, Fore (2007) produced a Tahoe Basin-specific macroinvertebrate multimetric index composed of seven metrics identified by careful documentation of the changes in invertebrate assemblages across a gradient of human disturbance. Data for this analysis were collected during 2003 at streams sites in ten tributary Tahoe Basin streams (Fore 2007). More recently, Herbst and Sildorff (2009) used data from 80 sites (134 site-date combinations) from a large geographic area—the eastern Sierra Nevada from the Upper Owens River drainage in the south to the Truckee River drainage in the north—to quantitatively define a ten-metric index of biological integrity (IBI) for streams within the region.

Although both efforts used robust statistical approaches to identify appropriate metrics and to combine them into multimetric indexes, differences in their approaches require additional evaluation to assess if and how they might be applied in the Basin. A model and analysis system generated with data from a large geographical area might, for example, be swamped by patterns not present a more focused region such as the Tahoe Basin but fail to identify and incorporate important patterns within the smaller region. Differences include:

1. Geographic area considered: Tahoe Basin for Fore; much larger and ecologically more diverse area for Herbst and Sildorff. The more diverse environments across the Eastern Sierra Nevada may influence our ability to identify and diagnose the causes of degradation within the Tahoe Basin. Only the western (California) portion of the Tahoe Basin is included in the eastern Sierra Nevada study region.

2. Number of sample sites: 171 streams sites for Fore; 80 sites (134 site-date combinations) for Herbst and Sildorff. Differences in density of sites between the two areas may influence interpretations of stream condition. About 20 of the Herbst and Sildorff sites are in the western Tahoe Basin.

3. Defining condition at site relative to standard: location along a biological condition gradient in Fore; percentage of reference condition in Herbst and Sildorff. A priori definition of sites as reference sites often includes sites with degradation, a factor that increases the range of variability among reference sites and influences interpretations that depend on percentage of reference condition.

4. Types of human activities used to characterize human influence affecting sample sites: eight factors (road crossings, percent development at site, conductivity, channel modification, percent erosion, large woody debris, human structures present, percent canopy cover) in Fore; two factors (road crossings upstream of site; bank erosion, largely from grazing, at site) in Herbst and Sildorff. Narrow analyses of factors responsible for degradation might miss changes caused by human actions.

5. Human influences in study regions [potential is from near pristine national park to major urban area]: Neither area has large urban or industrial areas. Most urbanized area probably in South Lake Tahoe region. Tahoe has legacy effects of logging and grazing. Sierra has both legacy and modern logging, grazing, agriculture, and mining. Transportation corridors occur in both study regions. Recreation and development are more important in the Tahoe Basin than in the broader Sierra region. Varying ranges of human influences may influence metric selection.

Each of these five factors could differentially influence the metrics selected for inclusion in a MMI/IBI as well as the precision and sensitivity of results and interpretation of Tahoe Basin river assessments. All should be examined and evaluated before final decisions are made on the best approach and index to apply in the Tahoe Basin.

To complete this objective, responsible agencies need to build on these efforts to refine biological metrics, define reference criteria, and establish specific biological condition targets (such as threshold standards) for urban and wildland settings within three years of implementation of a regional status and trend stream monitoring and evaluation plan. In addition to status and trend monitoring sites, selected reference sites in both urban and wildland settings will be sampled to establish scientifically credible biological condition targets for streams.

Section 2 – Overall Scope & Framework

This section captures the purpose and considerations that shaped the development of the conceptual model and indicator framework.

Purpose

The conceptual model and indicator framework for biological integrity of aquatic ecosystem—the stream biological condition objective—are intended to provide the context for resource managers to identify the factors and activities that drive biological condition of Tahoe streams. The conceptual model diagram is structured to accomplish several objectives. First, the CM avoids the common tendency to make everything simple, an approach that often leads to a focus on a single problem that can be "resolved" with a simple solution; reality requires a more multidimensional approach. Second, the CM is designed to frame the relevant issues in a comprehensive manner without burdening the reader or the manager with excessive detail. That is, we provide enough detail to help the reader identify the most influential factors and activities that are currently understood to drive stream biological condition. Third, the causal links between human activities and stream degradation are complex and the literature on these relationships is vast. The purpose of these documents is not to present the complexity of that detail. Rather, we avoid the detail characteristic of the research arena in an effort to summarize what we know and present a general scientific framework to structure management responses to degradation. We focus our text on:

- Refining the definition and intent of the desired condition by identifying a measurable objective, in this case Biological Integrity of Streams, as the benchmark against which all streams will be assessed
- Identifying the primary drivers (factors) that, on the basis of academic and local professional judgment or otherwise supported by technical references, most strongly affect stream biological condition.
- Identifying meaningful indicators to measure biological condition and drivers that affect stream biological condition.
- Assisting in the interpretation, evaluation, and reporting of stream monitoring and assessment data.
- Identifying the most influential management and policy actions to mitigate detrimental factors and achieve the desired condition and associated objectives.
- Identifying and defining research needs to reduce areas of uncertainty.
- Identifying and providing context for meaningful performance measures to track and report the accomplishments of management and policy actions.

Audiences & Uses

The conceptual model should be useful for communicating our current understanding of factors and activities that influence our ability to achieve desired condition with internal and external audiences.

Internal Audience – Agency staff and scientists who frequently use the conceptual model and indicator framework to plan actions and communicate the rationale for recommendations and decisions.

External Audience – Agency management and engaged stakeholders who will reference the conceptual model to understand recommendations and guide decisions. The CM is not designed to provide all the technical and scientific detail and foundations appropriate for an audience of research scientists.

Spatial Extent

This conceptual model covers the Lake Tahoe watershed with a specific focus on biological systems associated with streams.

Management Timeframe

The relevant timeframes over which the actions are expected to affect the desired condition depend on a stream's location and history. For example, if a stream in a wildland or forested area does not meet its targeted condition, implementation of best management practices may be the only change needed to restore the stream to its desired condition within a few years. In contrast, a stream in an urban setting may take decades to recover from the effects of historic land uses (e.g., channelization) and more recent urban development.

Limitations

- Biological monitoring and assessment has been successfully applied in more than 60 countries by scientists, managers, and policymakers in the past 30 years. Recent adaptations of widely used approaches to the Tahoe Basin (Fore 2007, Hebst and Sildorff 2009) provide the foundations needed to define a robust application to Tahoe.

- The relationships between, drivers, actions and their influence on biological condition is generally represented in this conceptual model. Details on specific mechanisms and stream processes are not detailed in the conceptual model diagram due to the need to provide a general understanding of key influences on stream biological condition to a broad audience. For example, the exact details on how new urban development results in soil disturbance which then sets up conditions for erosion are not explicitly provided. It is understood that erosion creates sediment that is then transported either directly or via a road network to a stream where is settles out in the stream channel and clogs the interstitial space of cobbles and gravels important for fish spawning and aquatic insects. In this case, the conceptual model diagram simply represents major natural and anthropogenic factors or influences known to elevate sediment loads to stream systems (such as "land cover and disturbance" and "climate and weather").

- The literature on the many subjects central to the organization and content of this conceptual model is massive. A superb, recent synthesis of information on the ecology, conservation, and management of streamside communities (Naiman et al. 2005), for example, includes a bibliography with 45 pages of citations totaling more than 800 published works on the subject. In development of this CM and supporting documents, we struggled to balance the need for simplicity and clarity with the need for detailed supporting information, including reference to relevant technical literature. We provide a modest bibliography as a central component of this CM to provide anyone wanting more detail with a listing of primary references and data sources. For some of those references, we insert a code to indicate some of the most relevant general (G), regional (R), and Tahoe-Basin specific (T) references.

- The conceptual model is based on best available science, academic and local professional judgment, and data available from Tahoe and elsewhere. The strength of linkages defined in the CM cannot be weighted with absolute certainty because effects on biological conditions are often a result of subtle or acute interactions among different controllable and uncontrollable drivers at a site. Moreover, these complexities make it impossible to specify precise mechanisms, no matter how desirable. For example, one might want to specify with a quantitative model the relationship between percent of landscape logged and sediment load in a channel or between sediment load and stream biological condition. Because all these factors are influenced by and influence other dimensions of stream condition (however measured) those models would inappropriately imply a sophistication in our understanding that does not exist. Consequently, in the name of consistency with other conceptual models developed as part of the program, linkage and factor weightings represented in this conceptual model represent the development team's best approximation of the relative strength of influences predominant in the Lake Tahoe Basin. Developers of the conceptual model recommend that stream practitioners conduct a focused diagnostic assessment after degradation has been indicated (from a biological condition indicator) at a site. That diagnostic assessment will help managers and policy makers determine more specifically what is contributing to degradation at that site. Participants should also recognize that the assessment process may identify factors that determine local stream condition beyond those deemed as responsible for most of the degradation at the landscape scale.

- Sampling and analysis of a single resident indicator (e.g., stream benthic macroinvertebrates) is an improvement over measures that emphasize chemical pollutants or physical habitat measures as surrogates of biological condition. The precision of estimates of biological condition can be strengthened and our ability to diagnose the likely causes is improved further when sampling and analysis protocols involve multiple resident indicator groups (e.g., measuring benthic macroinvertebrates, diatoms and soft algae, or fish communities).

- As a complement to the collection of biological data, the program to protect and restore the resources of the Lake Tahoe Basin is expected to collect data essential to the interpretation of stream biological monitoring. Selected measures of human activity in the watershed will be crucial as will carefully targeted information on stream and riparian physical environments (habitat) and water quality. But these should be targeted data collection procedures rather than comprehensive monitoring of all such features. Past monitoring efforts have too often tried to collect everything at everyplace, the equivalent of a doctor requesting a full array of medical tests from blood chemistry to CT scans each time a patient visits the office.

- This conceptual model does not explicitly address the potential impact of long-term climate change and associated effects on the stream biota. Nonetheless, the conceptual model implicitly recognizes that changes in hydrology, one of the major results of climate change, can have important effects on biological condition.

Considerations & Existing Understanding

This section provides stream-related background information, describes the factors considered in the development of the conceptual model diagram, and ends with a list of research and programmatic needs. See the Conceptual Model Diagram Overview section below, for a brief description of the most important factors and linkages shown in the conceptual model diagram.

Existing Understanding

- Aquatic organisms are the foundation of a stream system's food web. When the physical, biological, and chemical conditions necessary to support Tahoe's native aquatic invertebrate species are restored and maintained, goals will be achieved not only for biological integrity, but for a number of other related resource values related riparian zones (Morley and Karr 2002, Karr and Chu 1999).

- Decline in biological condition is typically the result of many forces acting in nonlinear ways. The cumulative effects of these forces can be large but the individual effects are often subtle, interactive, or uncertain. Solutions that treat only one such effect are not likely to halt or reverse a decline in biological condition. This complexity (nonlinear, multiple factors) also makes it difficult to predict accurately the next event that may affect the system. Effects are often contingent on or confounded by past and present effects of human actions and uncontrollable factors such as climate variation and the occurrence of unexpected events.

- Much progress has been made in the development of ways to measure the biological condition of aquatic ecosystems in the past three decades. Attempts to use that information alone or in combination with knowledge of local human actions to precisely define the specific drivers responsible for degradation are still incomplete.

- Current understanding of relationships between aquatic invertebrates and the effects of human actions is more developed than for any other major biological indicator group.

- Because of the complexity of these systems, we simply do not know everything we should know to ensure complete success. Adaptive management approaches should be designed and implemented to both improve our understanding of those relationships and inform stream management.

- The overarching goal of biological monitoring and assessment is to measure biological condition as a divergence from the minimally disturbed condition, sometimes called the "reference condition." Reference condition is the biological condition of aquatic ecosystems that is the product of evolutionary and biogeographic processes within a region, in the relative absence of the effects of modern humans. When biological condition is measured against that standard or benchmark, society as a whole can then determine if the level of divergence is acceptable given legal frameworks and mandates as well as the values (i.e., environmental, social, and economical) of local, regional, and national society.

- The aquatic invertebrate collection method previously used for pilot testing in Lake Tahoe streams should be replaced with the most current standard regional protocol (such as, state protocol for California [SWAMP], EPA EMAP, USFS Region 5 Stream Condition Inventory).

Biological Integrity of Streams Factors Considered

Altered Stream Habitat Features that Affect Biological Condition

The conceptual model identifies physical, chemical, and biological features that when altered outside of their natural range of condition are individually or in combination responsible for degradation of biological condition observed in Tahoe streams. The generalized nature of this conceptual model means that new drivers can be added to the existing structure without need for an entirely new model.

The descriptions are structured in an outline format to facilitate discussion. The factors shown in the CM diagram are enumerated. The factors not shown in the CM diagram are lettered.

Altered Physical Features

Rain and melting snow carve stream channels into the slopes surrounding Lake Tahoe and connect terrestrial environments (both their parts and processes) to the lake below. The channels of healthy streams are typically complex and diverse in substrates, water depth, and flow patterns. When human development and commerce alter the physical features of a stream channel or its surrounding watershed, the plants and animals living there respond in measurable ways.

1. **Habitat Structure.** Habitat structure refers to the channel bed particle size (e.g., silt vs. cobble), channel structure (e.g., straight or sinuous, pool/riffle ratio and sequences), the type of vegetation (e.g., plants vs. algae), and other physical features (e.g., coarse woody debris) of stream channels that provide places for organisms to hide, feed and reproduce. Although we know much about habitat configurations that are essential to the survival and persistence of many aquatic organisms, we should also recognize that many subtle aspects of habitat dependencies are not adequately known, especially for species with changing habitat requirements at different times during their life cycle. For example, a variety of small spaces between rocks or within plants provide essential environmental conditions for insect nymphs and larvae of different sizes. Human activities alter natural habitat by 1) direct removal of physical material (e.g., vegetation through harvest or land development) and 2) by simplifying the existing habitat (e.g., the homogenization of substrates caused by channel straightening). Sediment from eroding banks and other diffuse watershed sources (e.g., urban transportation infrastructure) can also degrade streams. The number of species found in a stream declines directly in proportion to the decline in the diversity of physical and biological environments available.
2. **Timing and Volume of Stream Flow (Flow Regime).** Flow regime refers to the diurnal, seasonal, and year-to-year patterns of water movement, including exchanges between the stream channel and the terrestrial landscape (e.g., floodplain connectivity) and between surface and groundwater. Vegetation and complex soil structure in the watershed absorb water and release it slowly. In contrast, the nonporous surfaces of human development (i.e., impervious surface) rapidly shed water to the stream channel. As a result, animals downstream of developed areas experience more intense flooding events and flashier flow regimes as the water moves faster from the land into the channel. Insects that live for multiple years are less likely to be found in streams with substantially altered flow regimes. Faster water is also more powerful and can move and deposit greater amounts of sediment which can also alter habitat structure as described above.

Altered Chemical Features

1. **Water Chemistry.** Water chemistry refers to the chemical composition and physical characteristics of water flowing through streams. Water pollutants (e.g., hydrocarbons, mercury, pesticides, and fertilizers) may be present in streams from a wide diversity of sources (e.g., parking lots, manicured lawns). Water is a strong solvent that can dissolve many substances while carrying them over, past, and through the plants and animals in a stream. Humans also add many chemicals to water bodies, influencing the survival and reproduction of many aquatic species. Water-borne pollutants may be difficult to detect in a one-time water sample but can bio-accumulate in lethal amounts within animals over time. For example, many aquatic species are especially sensitive to the presence of many contaminants because water flows directly through their gills used for respiration.

Altered Biological Features

The systematic collection of stream organisms, whether invertebrates or diatoms from stream substrates or fish from throughout the water column, provides much information about the condition of a stream. Samples collected from rocks and gravel on the bottom of streams, for example, can yield dozens of invertebrate species, primarily insect nymphs and larvae. Many amphibians, fish, and birds depend on invertebrates as food. Microscopic organisms and plants contribute further to the layers of life within a stream channel. Human actions affect the biological features directly in two major ways.

1. **Altered Energy and Nutrient (Food) Sources.** Energy and nutrient sources sustain plant and animal life in a stream. Algae and other plants turn the sun's energy into food while bacteria, fungi, and many invertebrates recycle dead material from sources as varied as fallen leaves to dead fish. Streams with diverse food sources yield many different sizes and types of food which, in turn, sustain a diverse assemblage of animals. Tahoe streams are home to many different invertebrate species even though they are naturally low in nutrients. When humans apply fertilizer or release sediment into the current, the suspended nutrients promote the growth of algae. Algal growth in the water column, in turn, blocks light to the native algae and animals living on the bottom of the stream. Animals that graze on algae may increase as visual predators decline. Humans also change the near-stream vegetation in ways that have substantial effects on the biota of a stream. These complexities are also important as influences on the presence and abundance of stream predators, including fish, birds, and mammals.
2. **Altered Biological Interactions**. Biological interaction refers to the web of potential connections between species and their influences on each other. The primary alteration of biological interactions in the Tahoe basin stems from the unintentional or deliberate introduction of invasive species (e.g., bullfrog) and non-native "desirable" species (e.g., rainbow trout). Introduced and "desirable" non-native species can increase diseases and parasite prevalence, elevate nutrient levels, increase predation rates, alter the character (e.g., singular plant species dominance) and availability of habitat for native species (through resource competition), and increase the potential for species hybridization.

Factors that Affect Stream Habitat Features

1. **Natural Features and Processes** have shaped landscapes, stream channels, and plant and animal communities present in Tahoe Basin streams for millions of years. Important characteristics of landscapes include weather and climate patterns and geological context such as geological origin, elevation, topography, and soils. The unique ecology[1] of the Tahoe Basin has produced diverse assemblages of stoneflies, mayflies and caddisflies when compared with sites in other areas of California and Nevada. Natural weather and climatic events such as drought, floods, and wildfire have also been part of the natural patterns in the Basin (native species have evolved adaptations to cope with these events), but can become more detrimental to stream biota when combined with human impacts.

2. **Human Land Uses and Practices**
   I. Wildland Areas: Historic – Although land uses and practices associated with resource extraction have been largely discontinued in Tahoe Basin, past resource extractions often have continuing legacy effects on the physical features of streams and their current biota. Historic forestry practices and the subsequent practice of fire suppression have resulted in single-age forest stands. Channel modifications associated with logging activities (e.g., dams, water extraction and diversions, flumes, stream channelization, and flood control impoundments) altered stream channel structure and watershed-specific hydrology. Widespread grazing damaged stream banks and soils, altered stream channel habitat structure through sedimentation and the simplification of riparian plant structure and composition. The introduction of non-native game species for sport fishing continues to alter biological features of streams. Finally, old septic systems and sewage management released nutrients and toxics into groundwater and

[1] Northern CA index scores and O/E scores indicated exceptional condition at many Tahoe Basin sites. The biological diversity and physical setting make the Tahoe Basin unique. The taxa are not unique.

surface water; the legacy effects on biological condition of these practices may continue to be expressed today.

II. Wildland Areas: Contemporary – Wildland areas are no longer intensely logged or grazed as in the past, but they are not entirely 'wild' either. Heavy machinery is used to remove or reconfigure vegetation to reduce wildfire risk and to a lesser extent chemical retardant is applied to suppress wildfires. Fuels reduction activities have the potential to compact or otherwise damage soils, elevate sediment loads in streams, introduce non-native species, and alter stream hydrology. Roads and trails often follow or bisect streams and contribute sediment to streams. Road crossings can confine streams and change a streams fluvial geomorphology as well as create barriers to fish migration. All these activities can increase the incidence of landslides on steep slopes. Introduction of new species may be intentional (sports fish) or accidental (New Zealand mud snails). The magnitude of effect on native animals and plants is difficult to predict although introductions rarely contribute to biological integrity goals. Within contemporary wildland areas, recreation areas (e.g., developed camp grounds, ski resorts) can produce effects that are similar to the effects of more intensive urban development. Although only a limited number of active dams remain in the basin, their influence can be substantial on the streams they are associated with. Dams create barriers to movement and migration of aquatic organisms, and alter natural stream flow patterns. In some cases, managers elevate stream flows during normally low flow conditions to accommodate the life cycle requirements of non-native species (e.g., fall spawning kokanee salmon) and otherwise limit the availability of spring stream flows to recharge reservoirs during critical spawning periods for native species.

III. Developed areas primarily surround the edge of Lake Tahoe and extend into the lower reaches of many streams. Several factors within developed areas are believed to significantly contribute to the alterations of key stream features including: 1) the urban transportation infrastructure, 2) land cover and disturbance, 3) urban landscaping practices, and 4) water withdrawal and export. Tahoe's urban transportation infrastructure and the associated maintenance is suspected of contributing to alterations to biological, chemical and biological features of streams. Roads contribute sediment and chemical inputs (associated with road de-icing activities, oil, grease, rubber, brake dust, etc.), thereby altering stream bed conditions and elevating chemical pollutant loads. Road construction and maintenance interrupt a watersheds natural surface and groundwater flow regime, often requiring stream channels and feeder tributaries to be moved or redirected. Road crossings confine streams from natural meander patterns, resulting in impediments to organism movements, stream bank instability, and channel downgrading. Land cover changes, a result of commercial and residential development and transportation infrastructure, increase impervious surfaces on the landscape, preventing water from naturally percolating into soils thereby affecting its rate of delivery to streams. Land cover primarily affects the physical characteristics of streams by rapidly shedding water to the stream channel. As a result, animals downstream of developed areas experience more intense flooding events and flashier flow regimes as the water moves faster from the land into the channel. Insects that live for multiple years are less likely to be found in streams with substantially altered flow regimes. Faster water is also more powerful and can move and deposit greater amounts of sediment which can also alter physical habitat structure as described above. Urban landscaping can affect the physical, biological, and chemical properties of streams by introducing non-native plants, elevating nutrient and toxic chemical loads (via use of fertilizer and herbicides) to streams, and alter natural watershed hydrology through grading and irrigation practices. Much of the water applied to lawns, golf courses, and other turf and landscaped areas is not treated before finding its way to a stream channel and the lake. Other chemicals or material from road surfaces, building surfaces, or landscaped areas can be dissolved by rain water and carried to the nearest stream and ultimately to Lake Tahoe.

All water used in the Basin comes from within the Basin, either from lake intakes, groundwater wells, or stream diversions. Wastewater is treated within the Basin and/or transported out of the Basin which may have implications for Tahoe's overall water budget. According to estimates published in 2000, about 2.4 billion gallons of water per year (about 1% of the total budget) are transported out of the basin that would otherwise contribute to Tahoe's aquatic ecosystem (Reuter and Miller 2000). In contrast evaporation accounts for 61% of the flow and 38% flows down the Truckee River. Perhaps more important than the gross amount of exported water is the source region for its loss; 26% (620 million gallons per year) comes as diversion from Echo Lake to the American River Basin and 74% (1.78 billion gallons) as water exported by sewage. Most of that comes from the urban areas at the south end of the lake.

Actions to Reduce Effects on Biological Conditions

Actions to reduce detrimental effects of human influence on biota vary according to type of disturbance and the nature of degradation; *not all* human activities alter biological condition of streams and thus cause a divergence from integrity.

1. **Actions for All Areas.** A variety of actions are appropriate for both wildland and urban areas. Development of effective educational materials is one such action. Visitors put considerable pressure on natural resources in the Tahoe Basin; they are also one of the easiest demographic groups to reach with educational materials. They frequent public places, are open to new experiences, and are engaged by the beauty of the Tahoe landscape. Programs are needed to limit the use of chemicals for home, lawn, and auto care by year-round residents. Government institutions, businesses, and homeowners and visitors should avoid introductions of non-native plants and other species. For other human activities, best management practices should be identified and continue to be implemented. Comprehensive watershed planning is critical to identifying specific actions that could be implemented within a watershed to improve stream biological condition.
2. **Actions for Stream Zones.** Streams can be protected by maintaining a buffer area around the channel in which minimal or no human disturbance is allowed. Dam releases can be managed to better mimic natural flow patterns. In streams where channels have been modified or altered, the land cover or alteration can be removed and the stream channel restored to conditions more characteristic of reference habitat conditions. Road crossings over streams can be modified from culverts to a more appropriate design that allows water, other substances and materials, and many aquatic species to move freely between breeding, spawning, and feeding areas.
3. **Actions for Wildlands.** Areas outside the urban boundary should continue to be managed primarily as forest habitat. For forested areas, best management practices for fuels reduction and road and trail maintenance should be applied (e.g., over-snow fuels treatment or other approaches that minimize soil disturbance, washing of logging equipment to remove invasive species), with special emphasis in areas adjacent to streams. Native vegetation and other non-forested land (e.g., rock outcrops and other undeveloped open spaces) should be similarly protected. To the extent possible, low intensity fire should be allowed or prescribed to play a role in the maintenance of forest ecosystem.
4. **Actions for Developed Areas.** We have identified three primary actions that can be taken for Developed Areas including: 1) Practice water conservation, 2) Transfer, buy out, or get

conservation easements on property and 3) maintain infrastructure. Urban areas affect a relatively small percentage of stream miles because the urban boundary represents a small percentage of total land area within the Basin. Nonetheless, these areas have a disproportionately greater impact on the plants and animals living in stream zones. Maintenance of existing buildings and roads or re-development of existing disturbed sites reduces the need to develop additional natural open space and, as a consequence, reduces human impacts on streams. Water conservation practices (e.g., low-flow appliances, water metering, and reduction of water withdrawal for maintenance of non-native landscaping) would improve water availability for natural aquatic systems. Buildings in sensitive areas (e.g., within stream buffers) should be identified for buy-out or land cover transfers out of streams zones; conservation easements could also benefit stream conditions. Roads maintenance, such as effective street sweeping, drop inlet cleaning, and regular repaving, can reduce sediment and contaminant loads entering streams. Actions to stabilize ditches and control water movement from transportation corridors to surrounding areas are also essential to prevent erosion. Improvements to road stream crossings that facilitate biota movement above and below crossing have proven beneficial to stream health as well.

<u>Factors Considered but not Included in the Conceptual Model Diagram</u>

a. **Pharmaceutical Residues (controllable driver, developed areas).** Water quality research and monitoring reveals that pharmaceutical residues are finding there way into stream systems via linked sewer treatment systems in other regions of the United States. Because wastewater is exported from the Tahoe basin, many people assume that this factor is not likely to significantly affect Tahoe's stream conditions and thus was not represented in the conceptual model diagram.
b. **Wildfire (uncontrollable driver, natural features, and processes**). Stand-replacing wildfire events can expose slopes and cause instability, release soil nutrients, and expose both natural and fire-induced hydrophobic soils, yielding substantial influences on surface water flows and timing of stream flow. Wildfire can also reset natural patterns of species replacement and succession in systems that have evolved with fire. Although wildfire represents a threat to a stream's biological conditions, wildfire was not included in the conceptual model diagram because effects are not likely to be widespread in the basin and it was presumed that native species impacted by such an event have adapted mechanism to re-colonize areas impacted by wildfire.
c. **Fire Exclusion (controllable driver, historic land uses and practices).** From the beginning of Comstock era logging to modern times, fire has not played a significant role in the maintenance of Lake Tahoe's forest ecosystems. The exclusion of fire from Lake Tahoe forest ecosystems was considered as a driver to stream biological condition because naturally frequent and low-intensity fire likely contributed to the structural and species diversity of riparian habitats. It is believed that fire exclusion has allowed for the encroachment of conifer species into riparian areas potentially resulting in an alteration of nutrient source and animal species diversity.
d. **Fire Suppression Operations (controllable driver, contemporary land uses and practices in wildlands).** Although fire suppression operations are limited in scale and historically infrequent in the Lake Tahoe Basin, the results of such operation can be detrimental to stream biological conditions. Typical activities of suppression operation include the aerial dumping of fire retardant, larger scale tree and snag removal, grubbing and bulldozing of soil. Such actions may result in the alteration of chemical composition of water, damage to soils, introduction of alien species, and the alteration of physical habitat features.

e. **Livestock Grazing (controllable driver, historic land uses and practices in wildlands) –** Livestock grazing was originally called out specifically but is now considered under "Comstock era logging and land uses." Remnant impacts from historic grazing have been documented in the basin. Currently, less than 60 acres of the basin is seasonally grazed. The associated contemporary effects of grazing were not considered significant when compared to the magnitude of other current land uses and practices, although it may be a major influence on stream condition in close proximity to those grazed areas.

f. **Septic Systems (controllable driver, historic land uses and practices) –** Historic management of sewage systems likely altered stream biological conditions. Since the adoption of the Porter-Cologne Act more than 40 years ago, most sewage is treated and exported from the Lake Tahoe Basin. Thus, sewage discharge is no longer a significant driver of today's stream biological condition.

g. **Low-impact Development (action, developed areas) -** Low-impact development was originally proposed as an action to reduce impacts associated with residential and commercial development. This action is still relevant and should be maintained as core policy related to residential and commercial development (coverage limitations, erosion control, building energy efficiency, etc).

Research & Programmatic Needs

- **Evaluate BMP effectiveness (Actions for All Area – Retrofit with BMP's).** Status and trend monitoring detects changes in stream biology relative to the desired condition objective, but the ultimate goal is to reverse any negative changes. The mechanism to accomplish this goal in many cases is the implementation of best management practices (BMPs); unfortunately, the relative effectiveness of many BMPs is not well known and some may have a detrimental (e.g., pumping storm water into natural wetlands as a means to settle out sediment and extract nutrients) rather than a beneficial effect on native plants and animals. Implementation of effective management plans will almost always involve carefully coordinated programs that employ multiple BMPs because of the complexity of cause and effect relationships among human actions and water body degradation.

Define numeric targets for desired condition (Objective – Biological Integrity of Streams). Numeric values that specify the reference criteria and biological targets or thresholds for both urban and wildland settings have not been defined for the Tahoe stream macroinvertebrate index. This task should be a core component of the stream monitoring program. Two approaches are widely used and recommended by EPA to define threshold values. One approach uses reference condition and defines a degraded site as outside the range of values for reference sites using some statistical criterion (see Herbst and Sildorff 2009 for an example). A second approach uses a panel of regional experts to fit biological values for an area's streams to a general framework of biological condition (Davies and Jackson, 2006). From that construct, experts define the amount of change in stream condition that would represent a departure from desired condition on biological grounds and with defined numeric ranges (see Clallam County Streamkeepers website for the definition of a five condition class system used in Washington's North Olympic Peninsula: http://www.clallam.net/streamkeepers/index.asp). Whatever method is used, it should be firmly grounded in an understanding of the biological context of that threshold. That is, it should be more broadly defined than an arbitrary statistical threshold.

- **Evaluate the relative merits of the Tahoe Basin MMI and the Lahontan IBI for application in the Tahoe Basin.** We suggest that a first level of study should involve calculation of the

Lahontan IBI for the Tahoe Basin data. Graph this against the Tahoe Basin MMI developed by Fore. If they have good agreement, then we recommend using this index for reporting purposes because it connects to the larger management framework. If the agreement is poor, and cannot be resolved, then we recommend calculating both indexes and use the Lahontan IBI to report at a regional level but use the Tahoe Basin MMI to manage within the basin.

- **Develop maps that document and illustrate landscape condition across the Tahoe Basin.** Accurate maps depicting the array of human actions that influence the Tahoe Basin landscape should be a priority activity. Within a GIS framework, map primary, secondary and smaller roads (including traffic levels and grading frequenct) along with surface cover type throughout the basin. Because of the importance of riparian zones as key influences on stream condition, road densities and landuse/landcover within riparian zones should also be carefully documented.

- **Fuel Reduction Treatment Effect on Stream Biological Condition (Driver – Wildland Areas, Fuels Reduction).** Over the next 10 years Basin land management agencies have established goals to treat greater that 65,000 acres (~1/3 of the Basin's land area, including treatment of riparian areas) for biomass removal. Although these treatments are well intentioned to reduce the potential for catastrophic wildfire through the reestablishment pre-settlement forest structure and composition, the effects of these activities occurring in a relatively short time period on stream biota are often associated with additional degradation of stream biological condition (Karr et al. 2004).

- **Effects of Road De-icers on Stream Biological Condition (Driver – Developed Areas, Transportation Infrastructure).** Concern for lake clarity has resulted in alternatives to the application of aggregate material to Tahoe's road network during winter months. Road management agencies have already initiated the use of a brine solution to roads as an alternate to aggregate material. Preliminary evidence suggests that this solution has already impacted vegetation along road corridors and has considerable potential to change Tahoe Basin streams in a way that may foster increase of the non-indigenous New Zealand mudsnail (Herbst et al. 2008). Little is known about other potential toxics (or their effects on streams) that may originate from Tahoe transportation infrastructure. An inventory of toxic chemicals in stream systems may be of value for targeting management actions to reduce this potential source of degradation

- **Water Withdrawal and Budget (Driver – Developed Areas, Water Withdrawal and Export).** Approximately 60,000 year-round residents and millions of visitors to the Lake Tahoe Basin annually represent potentially significant usage of water resources. For example, the South Tahoe Public Utility District reports that it maintains over 370 miles of water management infrastructure that collects, treats and exports over 1.5 billion gallons of water each year, 84% of the volume estimated as exported by sewage from the entire Tahoe Basin (Reuter and Miller 2000). Water extraction in combination with the export of treated sewer water that would otherwise be available for aquatic resources raises the following research questions: How does current water withdrawal affect stream biological condition and does the export of water significantly alter natural water budgets of selected Tahoe streams?

- **Road Crossing Condition Inventory (Driver – Forest Roads, Trails, and Culverts).** A comprehensive inventory and assessment of road crossings for both urban and wildland areas is needed. The inventory would provide managers with details on the location and type of crossing, while the assessment would document whether the crossing is contributing to the degradation of stream physical and biological conditions.

- **Role of non-native and invasive species (Driver - Altered Biological Features).** Non-native and invasive species occur with basin streams, but it is not clear how these alien species interact with native species and the extent to which native biological conditions have been altered by their presence. Research is needed to characterize the effect of alien and non-native species on native stream biota and to define what management actions can be taken to mitigate effects of alien and non-native organisms.

- **Stream Diagnostic Tools (programmatic need).** The conceptual model provides a regional understanding of factors and activities that affect our ability to meet stream objectives. However, managers would benefit from the development of tools and/or procedures that could be used to rapidly diagnose specific causal factors at sites where biological indicators signify degraded conditions.

- **Field Methodology (programmatic need)**. The invertebrate collection method previously used for pilot testing in Lake Tahoe streams should be replaced with the most standard regional protocol, e.g., state protocol for California SWAMP or the USFS Region 5 Stream Condition Inventory.

- **Data Management (programmatic need).** Streamline database management. Successful projects must have highly coordinated data collection, data management, and data synthesis plans. Streamlining of data entry is essential and it must be coordinated with existing data collection and management programs (e.g., California Environmental Data Exchange Network (CEDEN)).

Section 3 – Conceptual Model Diagram Overview

The following descriptive narrative links the biological condition of streams to key physical, biological and chemical habitat features (otherwise know as water resource features). Non-human natural features and processes (climate, geology) and human land uses (e.g., urban development) and practices (e.g., fertilizer application) drive changes to physical, biological, and chemical features of stream environments. Management and policy actions have been identified for “all areas,” “stream zones,” “wildland areas,” and “developed areas,” and are linked to human landuse and practices. Identified actions are intended to either fully mitigate or reduce the influences of human land uses and practices. The conceptual diagram provides a framework of human actions and management approaches with the potential to both halt negative trends and improve stream biological condition.

This section should be the starting point to orient readers to the conceptual model diagram. Consequently some of the descriptive material here repeats and summarizes the detailed information above.

Primary Chains of Cause and Effect

This conceptual model identifies the achievement of biological integrity targets for urban and wildland settings as an objective. Meeting these targets depends on the condition of biological, physical, and chemical features that interact with stream zones. Human alteration of a steam’s natural hydrologic regime, habitat structure, food resources, biological interactions, and/or water chemistry can impact a streams ability to support plants and animals that have evolved in this region.

Major natural features of the Tahoe Basin such as climate, topography, and soils have influenced the biota of the region for hundreds of thousands of years. The addition of humans to the region more than 10,000 years ago set in motion changes that accelerated dramatically in the last 150 years.

Tahoe's landscape has been dramatically modified when compared to the landscape that existed prior to European settlement. A suite of historic and contemporary land uses and practices are now part of Tahoe's landscape and are called out as factors that are likely affecting water resource features important to a stream's biological condition. Contemporary human land uses and practices in wildlands and urban areas also influence stream condition, either as new factors (new toxic chemicals, road networks, or construction activity) or continuation of old factors (soil erosion from disturbed areas, spread of non-native species, channelization, and water control structures).

Human land uses and practices have changed the biology of Tahoe Basin streams. Sometimes the changes result from direct human actions on stream biology; sometimes effects are more indirect, such as when water quality, physical habitat structure, and flow regimes are altered. A major goal of this conceptual model is to provide guidance to managers and political leaders that will help them track and interpret the scientific assessment of the status and trends in Tahoe Basin streams.

It is challenging to single out the most influential land uses and practices because impacts to biological conditions are a result of subtle and/or acute interactions among different biological, chemical, and physical factors. Nonetheless, this conceptual model identifies alterations to physical habitat features (namely habitat structure and stream flows) as a primary stressor to Tahoe stream biological condition. Alterations to physical features are primarily a result of contemporary and historic landuses and practices. Actions to reduce impacts to stream biological condition are also difficult to prioritize because each action has merit and could result in incremental benefits to a stream's biological condition. This conceptual model identifies the set of actions associated with "stream zones" as one of the most effective means to reduce effects on biological condition because this zone most directly influences stream habitat conditions. Other actions are especially critical within developed areas including the maintenance of transportation infrastructure, the practice of BMP retrofitting, and coverage transfer and buy-out programs,

Overall, the conceptual model provides a road map to ensure that the most relevant data are collected to guide human actions and management protocols that will reduce the human footprint on the biota of Tahoe Basin streams. These actions will also reduce the effects of human actions on the water clarity and biological condition of Lake Tahoe.

Summary of Management Actions

The management actions expected to improve or reverse the decline in stream condition are organized into four sets: actions for all areas, for streams zones, wildlands, and developed areas.

<u>Actions for all areas (included in conceptual model diagram)</u>

> **Educate public:** The public needs to understand the many reasons for maintaining healthy streams as well as how to contribute to such goals. An example of the type education material could include proper handling of fishing equipment to avoid the introduction of alien species and understanding of the importance of channel and riparian environments as determinants of stream condition.

Minimize chemical use: The twentieth century has witnessed a proliferation of chemicals used by human society (pesticides, fertilizers, and toxics). The use of many of these chemicals can be detrimental to the biota of streams. Limiting chemical use will be crucial to the success of this program.

Emphasize native species: Native species that have evolved in a region are typically best able to sustain themselves without management intervention and do not contribute to detrimental effects on local and regional ecosystems. Projects and management actions (whether associated with streams or not) should specifically include design considerations that promote native species and avoid the introduction of non-native species. Introduction of non-native species can have devastating effects on native ecosystems. Preventing the introduction of invasive species is typically easier than removal.

Retrofit with Best Management Practices (BMPs): Throughout the last 150 years, human actions have created legacy effects that continue to degrade stream biology and to prevent recovery. Best management practices include measures to treat urban and forest road runoff, avoid the introduction of non-native species, and control sources of sediment.

Watershed Planning: Watershed planning can be an effective means of characterizing the unique and specific impacts to stream condition operating within a given watershed. Planning can focus managers by providing a list of prioritized actions that can be implemented to reverse degradation to biological resources.

Actions for stream zones

These are actions for zones in the stream channel and riparian areas adjacent to the channel.

Protect and buffer stream zones: One of the most important actions to improve water quality and the biological condition of streams is to protect the stream zone from permanent incursions by human actions such as residential and commercial development. Any construction or modification of the physical stream channel, no matter how temporary, should be avoided because these environments are very difficult to restore successfully.

Restore/enhance channels: Manage dam releases; reestablish, reconnect or enhance watershed hydrology; reconnect stream channels to adjoining floodplain; improve the design of road and trail crossings; and realign stream channels consistent with the geomorphic setting.

Actions for wildlands

A variety of wildland areas have been modified historically and many continue to experience various pressures from humans.

Implement/require appropriate forest land use practices: Many of the effects of human actions on streams can be reversed by honoring and implementing effective forest management standards and practices. Existing forest practice standards include provisions like stream setbacks, placement of structures, road and trail design criteria, timing of timber management activity, minimum snag and coarse woody debris retentions standards, and soil protection standards.

Actions for developed areas

The most detrimental effects of human actions are most likely to occur on urban streams. Several classes of actions are important to halt or reverse these trends.

Maintain infrastructure: High quality and well maintained transportation (e.g., street sweeping), building (sediment source control BMP's), and flood-control infrastructure (e.g., storm water treatment) is essential for healthy streams. From roads to utility distribution, high quality infrastructure is essential to minimize the influence of human development on the health of urban streams.

Practice water conservation: Removal of water from either groundwater or surface water influences both the flow and physical structure of stream channels. Excessive landscape watering releases nutrients and sediment that alter the biological composition and interactions of stream biota. Water conservation benefits stream condition in multiple ways.

Transfer, buy-out, or get easements on property: Creative use of these instruments can make key direct and indirect contributions to the improvement of stream health as measured by biological condition. This action includes the protection of undeveloped/undisturbed land from being developed and the enhancement or restoration of lands that have been developed within stream zones.

Conceptual Model Connections

Through the review of all Pathway desired condition statements and supporting documents, several desired conditions relate to aspects of stream and riparian system conditions. Consequently, the drivers, actions and relationship identified in the stream biological integrity conceptual model may be applicable to other stream-related desired conditions or to the development of conceptual models for application to other aquatic ecosystems within the Tahoe Basin. In the interest of reducing redundancy, overlapping desired condition statements may, in some cases, preclude the need to develop additional conceptual models for other desired conditions identified by the Pathway process. Related *Pathway* desired conditions that address stream systems include:

Water Quality - Human and Environmental Health:
- *Water quality conditions in the Lake Tahoe basin protect human and environmental health.*

Stream Environment Zones - Biological Function
- *Stream Environmental Zone biological processes function properly within the constraints and dynamics of the watershed; Vegetation, terrestrial wildlife, and aquatic communities are healthy and sustainable.*

Stream Environment Zones - Physical and Chemical Functions:
- *SEZ Physical and chemical processes function properly within the constraints and dynamics of the watershed, including, but not limited to, natural hydrologic processes, water quality, and stormwater treatment capacity.*

Soil - Land Coverage and Disturbance:
- *The effects of impervious cover and increased runoff are attenuated to enhance and protect soil and Stream Environment Zones (SEZ) resources on a stormwater-zone basis. Land coverage does not exceed the capability of the soil resources to offset the effects of impervious cover. The effects of land coverage and disturbance are fully mitigated on a stormwater basis.*

Vegetation - Healthy Forest and Vegetation:
- *A full range of native species, developmental stages, habitats and ecological processes occur.*

Section 4 – Indicator Framework

An indicator framework diagram provides an illustration of the relationships of data sources with indicators used to evaluate whether a target is achieved. It is intended to quickly provide the reader with an understanding of the origin of information (in the form of a dataset), and the metrics, indexes and/or indicators used to evaluate the status of a resource of interest, in this case the biological condition of streams. When the indicator framework is populated with information provided from field or laboratory efforts, the indicator framework will be used to show the status of each indicator relative to targets, the trend of the indicators relative to previously document monitoring results, and the confidence in: 1) the source of the data (i.e., do data gaps existing or has the data been quality checked?) 2) status of the indicator (has there been sufficient sampling effort to determine status) and 3) trend in the indicator (level of confidence that the reported trend is in fact occurring). The indicator framework must be usable by decision-makers and technical audiences to:

1. Display the numeric status, trends, and confidence information so that users can understand where ecological or socioeconomic concerns are emerging
2. Understand how higher-level indexes are aggregated from lower-level data
3. Clearly see when lack of data prevents calculation of upper-level indices or contributes to reduced confidence in evaluation of indicators
4. Detect where information or conclusions about desired condition are less robust than desirable in order to enhance the cost-effectiveness of data collection and analysis

The indicator framework consists of this supporting narrative, which includes a simple diagram, and a table that describes the specifics of each part of the indicator framework. The following sections explain the simple diagram of the indicator framework, and overview themes and key points of the indicator framework table. The indicator framework table is included in the conceptual model and indicator framework spreadsheet file.

The Biological Integrity of Aquatic Ecosystems and its Biological Integrity of Streams Objective indicator framework described here is preliminary. Information provided here sets the stage for a process to show the origin of and how benthic macroinvertebrate data are evaluated to determine achievement of the stream condition objective, that is, attainment of the biological integrity goal. Both the conceptual model and indicator framework are intended to be revised regularly as new information becomes available or as technical reviews provide constructive input for improvement.

Diagram Description

Figure 2 provides an overview of the data nodes and data connections for the Biological Integrity of Aquatic Ecosystems – Biological Integrity of Streams Objective indicator framework. Each shape in the figure is referred to as a data node. The data nodes will contain information on status, trend and confidence once data are available as well as the rules for aggregating different measures related to the stream biological integrity objective and ultimately the biological integrity of aquatic ecosystem desired condition. The numeric connections, shown as black connecting lines, represent the aggregation calculations used to combine lower-level data into synthesized, higher-level information.

Datasets not connected represent supplementary data that may be used to characterize causal agents influencing the status of an indicator. Stars on a data node indicate that maps or other spatially explicit data are important to consider. Black diamonds on the edge of a shape indicate that further development of that data node is needed.

Data Nodes

The indicator framework for the Biological Integrity of Streams Objective includes five specific shapes to depict the kind of information represented (Figure 2). For the purposes of this description, shapes occupy a specific tier and contribute to the tier above them. The shapes are described from the bottom of the diagram to the top.

- **Datasets –** Depicted as cylinders at the bottom of the IF diagram, datasets include measurements and information derived from field efforts carried out by TRPA, Lahontan, USFS, NDEP and other agencies. Data from different agencies will be combined and accessible through the Regional Stream Bioassessment Database. Benthic macroinvertebrates field collections are included in the database as taxonomic lists of species with the number of individuals found at each stream site.
- **Metrics or Indices –** Depicted on the next tier as round-shouldered rectangles, metrics are measurements of a single variable within a dataset, while an index is an aggregation of more than one metric. A metric or an index can become a status indicator if a target or threshold value is established. Benthic macroinvertebrate samples for each stream site-visit are summarized as metrics including: number of caddisfly taxa, long-lived taxa, stonefly taxa, intolerant taxa, clinger taxa, EPT taxa, and percent non-insect taxa. To combine metrics into a multimetric index (MMI) for Lake Tahoe Basin, metric values are converted to unitless scores (Fore 2007). Metrics were scored from 0 (indicating worst condition) to 10 (indicating best condition) using the 10th and 90th percentile values using 171 stream samples. The Lake Tahoe Basin MMI is the sum of the six scored metrics divided by 0.6 to yield a final MMI that ranged from 0–100. Other regional indexes may be calculated from the benthic macroinvertebrate data, e.g., the Lahontan IBI developed for the eastern Sierra (Herbst and Silldorff 2009) and the index of observed vs. expected taxa (O/E) for California (Hawkins et al. 2000).
- **Status Indicators –** Depicted on the next tier as rounded rectangles, status indicators provide numeric information about an objective of a DC. Status indicators are distinguished from metrics and indices by the inclusion of defined starting point and target values. For the Tahoe Basin numeric targets have not been defined for the Tahoe Basin MMI. One approach to defining target values used reference sites to set expectations for other areas (Stoddard et al. 2006). Additional reference sites were sampled in 2009 and this information can be used to define target. An alternative approach uses the biological condition gradient to standardize biological measures across categories of condition to define thresholds for impairment (Davies and Jackson 2006). Once targets are defined for the MMI, status will be reported as the percentage of stream miles with MMI values equal to or greater than the target value for each land use designation (e.g., wildland or urban). Because a probabilistic survey design will be used to select stream sites, status indicators will also have a confidence interval associated with percentage estimates of stream miles meeting target conditions.
- **Objectives –** Depicted as ovals, objectives in the desired condition framework directly correspond with objectives from the CM and represent quantitative targets interpreted from DCs. Objectives have not been defined for streams, but could be written as “90% of stream miles in wildland areas should have MMI values greater than or equal to 70” and “80% of stream miles in urban areas should have MMI values greater than or equal to 50.” In the indicator framework, these types of expression are called “percent-to-target,” that is, the percent of stream miles that are meeting the target condition. A related objective could be defined for change in stream condition as “MMI values at trend sites should improve or stay the same,” that is, no declining trend should occur. Finally, MMI values could be defined for specific sites deemed as important to determine if specific goals for those sites are being attained.

- **Desired Condition** – At the top tier, the desired condition value may be an aggregation of values for several objectives. For now, the DC only derives from the biological integrity of streams, but objectives for Lake Tahoe, small lakes and wetlands will eventually be added.
- **Supporting Datasets** - Supporting datasets are not included in the numeric aggregation to the DC status, but can be used to qualitatively interpret changes in the status of the DC. The extent and intensity of wildfire or beetle outbreaks, for example, could be useful as supporting datasets.

Aggregation of Data Nodes

Moving up through the tiers of data nodes, information is aggregated using some form of quantitative analysis. When data are in the same units, weighted averages are most common. When data are not in the same units, other techniques are used, such as converting to unitless scores. For now, only stream benthic invertebrates are included to evaluate the desired condition for aquatic ecosystems, but when other resource types are added, objectives for each group must be aggregated. One approach would be to weight the objectives according to the watershed area they represent.

For reporting, some restoration programs use a summary statistic known as percent-to-target. This method can be used to summarize data at different tiers once benchmark values are defined. Using the status indicator for streams, for example, the percentage of stream miles meeting the target value for MMI (the percent-to-target value) can be reported. At the next tier for the objective, we might define the expectation in terms of the percentage of stream miles expected to meet their target. If that type of target were met for streams but not for wetlands or small lakes, we would say that the percent-to-target was equal to 33%. Similarly, for other higher-level data nodes (not pictured), percent-to-target can be used to summarize across all the desired conditions for the Lake Tahoe basin.

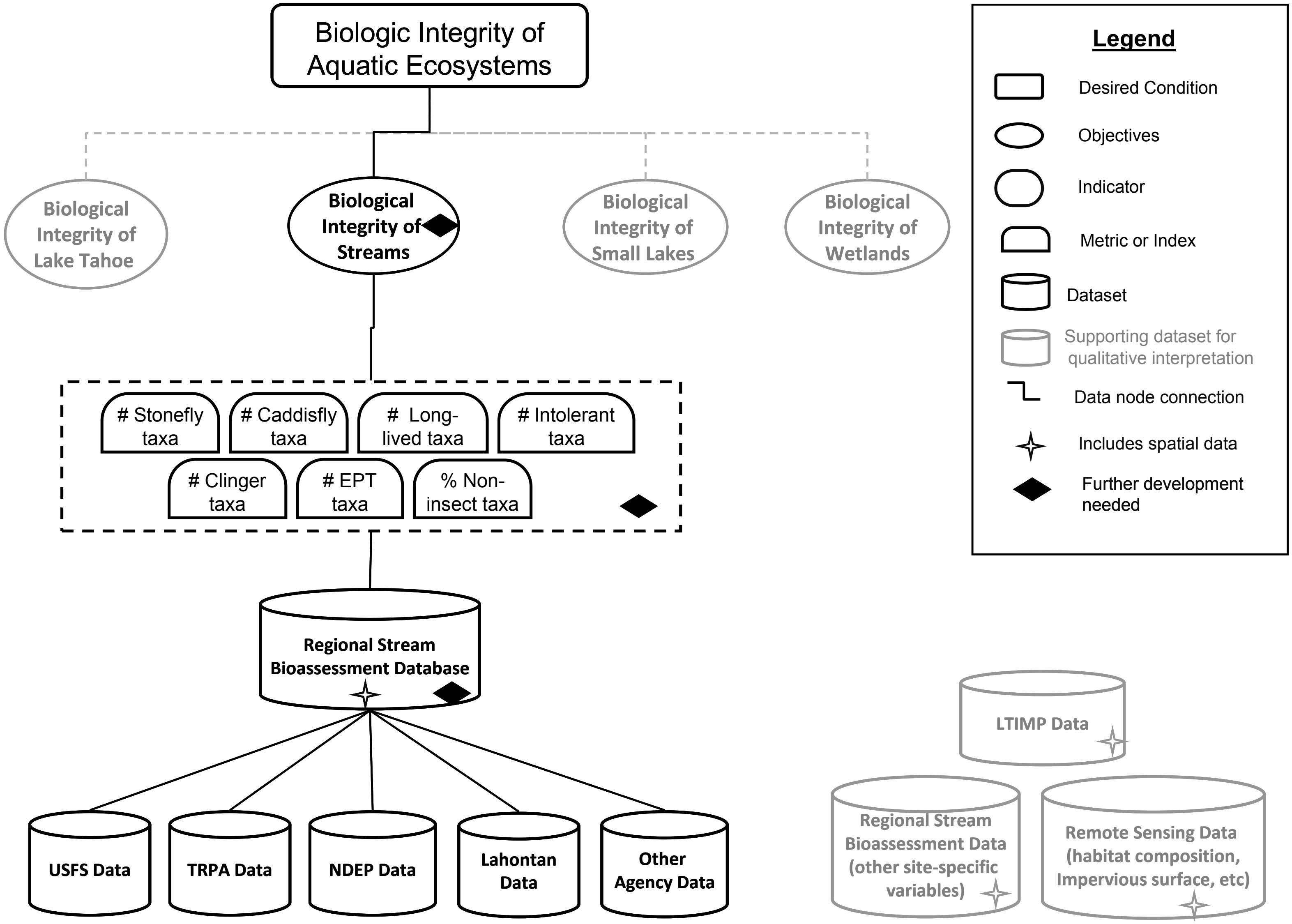

Figure 2: Each box in the figure represents a data node that can include status, trend and confidence information about different measures related to the Biological Integrity of Aquatic Ecosystems desired condition – Biological Integrity of Streams Objective.

Indicator Framework Table Overview and Themes

Additional detail and references regarding the data nodes and calculations needed to aggregate data into summary indexes are provided in the indicator framework table that is part of the CM & IF Spreadsheet file.[2] For each data node, the IF table contains information detailing:

- where data come from
- calculations necessary for aggregating to higher tiers, including target and benchmark values
- rules for when status assessments are or are not possible
- considerations necessary for analyzing trends
- methods used to estimate confidence
- additional references that support the IF table

Status Monitoring

To assess the status of a resource, such as streams in the Tahoe Basin, the best approach randomly selects as many sampling sites from the population as possible (Larsen et al. 2001; Ode and Rehn 2005). Random sampling ensures that any summary statistics derived from the sites visited will be representative of the entire population, including all the sites that were *not sampled* (Stevens and Olsen 1999). In addition to an unbiased estimate of overall condition, the uncertainty, or variability, associated with any estimate of stream condition can be derived for the entire population (Stevens and Olsen 1999).

For Tahoe Basin, the population to be sampled can be defined as all tributary streams in the Basin. Exceptions to this definition of the population might include stream sites close to the lake where a stream transitions to lentic habitat. Streams must also have adequate flow and depth to enable sampling. Other sites could be excluded from the population if they are of less concern, such as sites within protected areas or sites that are outside the management purview of the agency.

Within the population, sampling units must be defined. Sampling units are the elements of the population that are actually measured. For medical surveys, a person is typically the sampling unit. In contrast, rivers and streams are continuous resources and do not form simple, discrete sampling units; therefore, some method must be used to delineate stream sections into sampling units. Many of these issues have been resolved and specific software has been developed to randomly select sampling locations from continuous resources such as rivers, estuaries, and reefs (USEPA 2006).

Sampling effort can be apportioned among types of areas. For example, straight random sampling would put a high percentage of sites in wildland areas. If desired, selection criteria can be adjusted so that, for example, 50% of the sites sampled are from both wildland and urban areas. Sampling would still be random, but effort would be allocated according to type of land use.

Trend Monitoring

The goal of trend monitoring is to detect a change through time should a change occur. The best sampling designs for detecting trends initially select sampling locations randomly, but then re-visit the same locations either every year or in a rotating pattern (e.g., every fourth or fifth year; Urquhart et al. 1998)). The recommended statistical model for trend detection is a regression model in which the variable of interest, e.g., a multimetric index of stream condition, is regressed against time. Sampling designs in which the same sites are visited each year have the greatest power to detect a trend because each site is

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[2] It would be helpful for the reader to have this file available while reading this section of the narrative, to facilitate complete understanding of both the IF diagram and table.

effectively compared with itself through time. In contrast, selecting a new random set of sites each year introduces a large amount of variability due to site differences and makes it more difficult to detect trends.

Some flexibility is possible for status monitoring such that more or fewer sites may be sampled in a given year. In contrast, the trend sites are not flexible. Once trend sites are selected within a region, they must all be sampled during their rotation year. The statistical model (MMI for sites regressed against year) assumes that the same sites are sampled during each time period which could be every year, every other year, or every fifth year according to program needs. If a site is not sampled in a particular year when it was originally planned to be sampled, data collected from that site for *all years previously sampled* must be removed from the analysis. Sites cannot be substituted or replaced because the trend model works by comparing each site to itself through time. Comparing the same sites through time is the most sensitive model for detecting change.

Certainty

Confidence levels should be reported with any summary of resource condition. Summary statistics derived from a random survey include an estimate of condition, e.g., the percentage of stream miles meeting target values for the MMI, along with an estimate of variability. Thus, a statistical survey design would yield estimates such as "60% +/- 8% of urban streams in the Tahoe basin met their target MMI value."

Datasets, Metrics and Indices – Variability can be calculated from repeat visits to a site within a single year or across years. Certainty at this level is derived from the variability of field observations and results can be used to modify the field collection protocols if necessary.

Status Indicators – Certainty at this level is derived from the statistical survey design and reported as the variability associated with estimates of the percentage of stream miles meeting their target MMI value.

Objectives & Desired Conditions – For now, only a single objective (stream ecological integrity) is provided for the desired condition of aquatic ecosystems. When objectives are added for Lake Tahoe, small lakes, and wetlands, some measure of certainty is needed when the status indicators for the different resource types are combined. Because the resource types do not overlap, a numeric estimate of variability can be derived based on the amount of area represented by each resource type.

Extended Methodology Descriptions

Reporting

In order to standardize information across the various desired conditions for the Lake Tahoe region, the use of percent-to-target statistics is recommended. Managers are not limited by this design to these indicators. Other comparisons and analyses can be made; comparisons of benthic invertebrate field samples before and after implementation of best management practices (BMP) in the watershed can be used to evaluate the effectiveness of BMPs. Stream condition could also be compared according to land use types or other features. Within a different spatial grouping, summary statistics and confidence intervals can also be derived and reported. These types of comparisons are needed to determine the sources and causes of degradation and to develop management practices that can successfully restore and protect streams and their biota.

To integrate across programs, simple summary statistics are needed. Nonetheless, simple statistics (e.g., percent-to-target of stream miles meeting benchmarks for the benthic invertebrate MMI) are not capable of determining whether current management practices adequately protect aquatic ecosystems. Additional data and information should be used to make this determination and to manage the resource. For example, exceptional sites should be protected and monitored for their own intrinsic value rather than lost in the mix of sites and their condition allowed to decline to the target value. Improvement in degraded sites should also be tracked specifically so that management decisions in those watersheds can be applied across the basin to improve other streams.

Ranking and Assumptions – CM table

This narrative document is accompanied by a set of tables for the CM and IF. The table for the CM requests that we rate the factors included in the CM to identify the importance of each factor. The ratings are then to be used to combine factors and report them across the various conceptual models developed for the Lake Tahoe basin. The relative importance of drivers, their influence, and uncertainty are examples of qualitative ratings that are combined and reported to prioritize management decisions. Although we have developed these rankings for stream ecosystems, we do not endorse their use to establish priorities for decisions that will be used to define management strategies or research priorities. These preliminary ratings and the simplistic rules for combining them are simply not robust enough for that use at this time.

The long-term goal of using summary indicators as one measure of program success and for decisionmaking is important. But such uses should be tempered by an understanding of how such summary indicators can conceal important and ominous trends in resource condition. Some of the best locations within the basin could be declining significantly but the trend not detected when aggregate data across many sites are examined.

Primary References & Data Sources

Our specification of factors to be included in the conceptual model is underpinned by nearly four decades of research on the measurement of stream condition and the diagnosis of factors responsible for stream degradation. Literally hundreds of scientific papers, books, and reports have informed our judgments in developing this conceptual model and the indicators used in its application to the Tahoe environment.

The primary reference documents and sources informing this conceptual model and indicator framework include the following coded according to their conceptual or geographic area of focus in three groups: G–General; R–Regional; and T–Tahoe Basin.)

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Biological Integrity of Streams
Conceptual Model

Version 0.64
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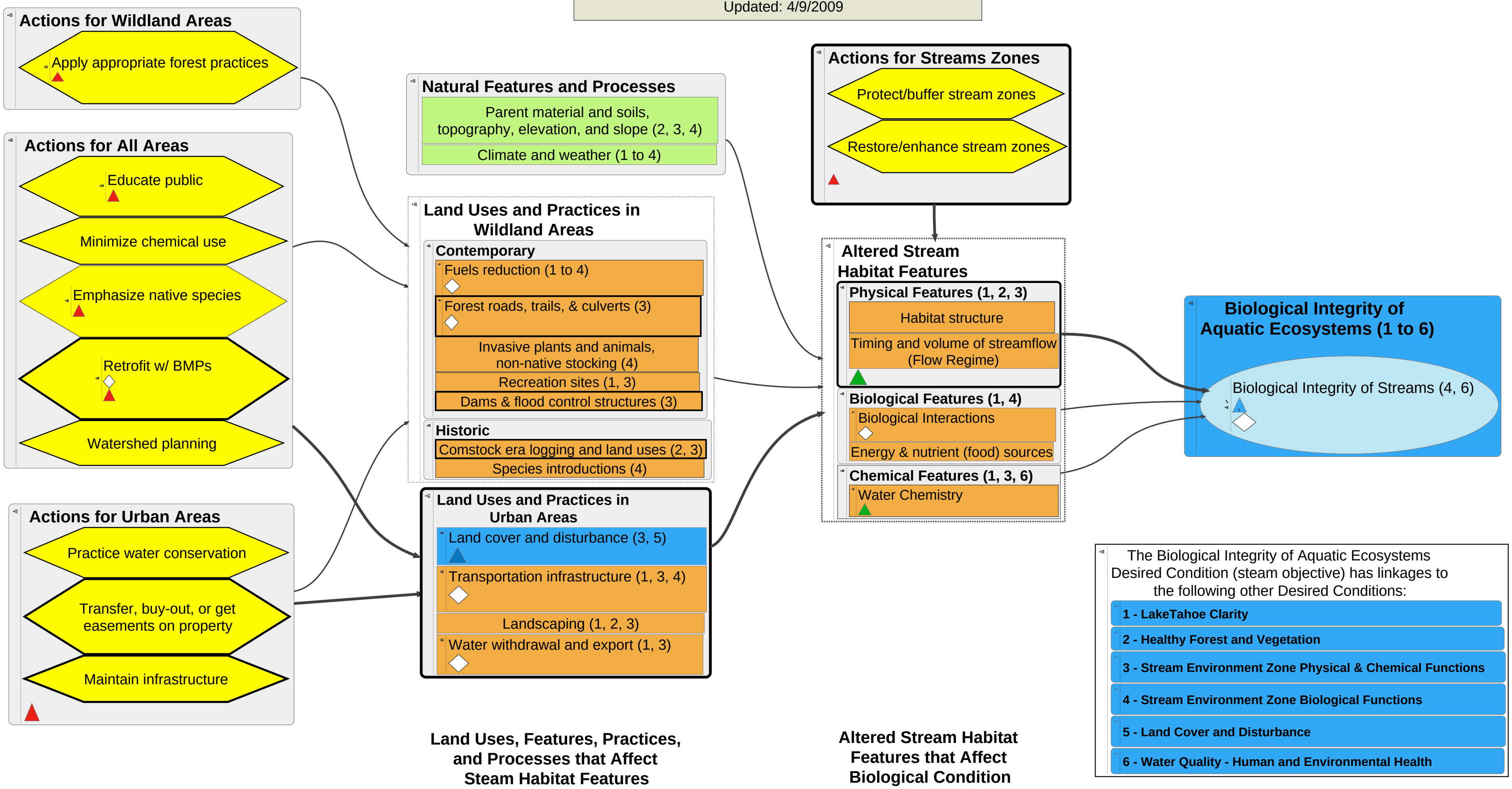

This conceptual model is part of the Lake Tahoe Status and Trend Monitoring and Evaluation Program. For additional materials or information, contact Shane Romsos, TRPA, email: sromsos@trpa.org, 775.589.5201